

STUDIES ON WESTERN AUSTRALIAN PERMIAN BRACHIOPODS

4. PRODUCTELLIDAE SCHUCHERT & LE VENE 1929 AND OVERTONIIDAE MUIR-WOOD & COOPER 1960

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ABSTRACT: Productellidae and Overtoniidae (Productida, Brachiopoda) from the Early Permian sequences of the Carnarvon Basin, Western Australia are described. The following species are revised or described: *Stictozoster senticosa* (Hosking), *Comuquia australis* sp. nov., *?Lethamia obscurus* sp. nov., *Dyschrestia micracantha* (Hosking), *Dyschrestia colemani* sp. nov. and *Dyschrestia* sp.

This paper continues the series of studies on Western Australian Permian brachiopods (Archbold 1983). Representatives of the Productellidae and the Overtoniidae are restricted to the early Permian sequence of the Carnarvon Basin. None of the species are common. The stratigraphy of the Carnarvon Basin is documented in references referred to in Archbold (1981, p. 109). The basis for age assignment of species is also outlined in Archbold (1981). Terminology is standard as in previous studies.

COLLECTIONS

All figured and measured specimens are housed in the following institutions as indicated by the prefix to the registered numbers. CPC—Commonwealth Palaeontological Collections of the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. GSWA—Geological Survey of Western Australia, Perth, Western Australia. MUGD—Department of Geology, University of Melbourne, Parkville, Victoria.

SYSTEMATIC PALAEONTOLOGY

Order PRODUCTIDA Sarycheva & Sokolskaya 1959
Superfamily PRODUCTELLACEA Schuchert & Le Vene 1929

?Family PRODUCTELLIDAE Schuchert & Le Vene 1929

Genus **STICTOZOSTER** Grant 1976

TYPE SPECIES: *Stictozoster leptus* Grant 1976.

DIAGNOSIS: The diagnosis provided by Grant (1976, p. 96) is accepted.

DISCUSSION: Grant (1976) discussed the combination of features of this peculiar genus, noting that *Stictozoster* does not fit readily into any established family, however, the present author follows Grant and retains the genus provisionally within the Productellidae, 'extending the range of that family on somewhat doubtful grounds' (Grant 1976, p. 96).

Grant (1976) referred no other species to this genus although he did indicate that *Pustula senticosa* Hosking 1933 belonged to *Stictozoster*, an indication substantiated herein. Several other species, although known only from ventral valves, appear distinctive enough to assign to *Stictozoster*, as summarised by Archbold,

(1982b, p. 9) and, in part, independently by Waterhouse (1981, p. 74). Waterhouse (1981) however, disputed the generic position of *S. senticosa* and suggested that the species belonged in *Lethamia*, a genus that has subsequently been fully described and figured (Waterhouse 1982a). *Lethamia ligurritus* (see Waterhouse 1982a, pl. 8, figs c-i; pl. 9, figs a-j) is of comparable size to *Stictozoster senticosa* but the dorsal septum of *S. senticosa* is delicate, thin and not raised anteriorly as in *Lethamia*. The large size of the only available dorsal valve of *S. senticosa* (width 30.6 mm) indicates that the specimen is not a juvenile. The dorsal septum of *S. senticosa* together with the concentric bands of minute pustules strongly resembles those of *Stictozoster leptus* (Grant, 1976, pl. 17, figs 18, 19). The main difficulty in assigning '*Pustula*' *senticosa* to *Stictozoster* is the ornament of external coarse spines (much coarser than those of *S. leptus* and species of *Lethamia*), but the dorsal interior features are taken to be more diagnostic. The cardinal process of *Lethamia* appears to be similar to that of *Stictozoster*.

Stictozoster senticosa (Hosking 1933) Fig. 1A-H

- 1933 *Pustula senticosa* Hosking, p. 47, pl. 3, figs 2-3.
1937 *Pustula senticosa* Hosking; Raggatt and Fletcher. *Rec. Aust. Mus.*, 20: 176.
1943 *Krotovia senticosa* (Hosking); Prendergast, p. 30.
1957 *Krotovia senticosa* (Hosking); Coleman, p. 63, pl. 7, figs 11-15.

LECTOTYPE: GSWA1/4970a1; Hosking, 1933, pl. 3, figs 2a, b. Chosen by Coleman (1957, p. 63).

MATERIAL, AGE AND LOCALITY: Hosking's (1933) syntypic series of 3 conjoined shells, all crushed, 1 with much of the dorsal interior exposed, GSWA 1/4970a1-1/4970a3, all from creek 0.75 km west of Callytharra Springs, Wooramel River; Callytharra Formation; Sterlitamakian (Late Sakmarian).

MEASUREMENTS (in mm): Lectotype*, e = estimate

Specimen number	Maximum width	Hinge width	Ventral height	Dorsal height
GSWA1/4970a1*	23.5	16.7	17.1	15.5
GSWA1/4970a2	30.6	22.0	23.2	20.8
GSWA1/4970a3	28 e.	20 e	20.6+	18.0+

DIAGNOSIS: Large *Stictozoster* with coarse spines widely spaced. Dorsal interior characteristic of genus.

DESCRIPTION: Outline transversely subelliptical; shell concavo-convex, visceral cavity thin, non-geniculate; hinge width about two-thirds of maximum width, hinge ends rounded; valves thin, no thickening at hinge; maximum width at midlength of shell; both valves covered with spines, those of dorsal valve being finer; ventral spines undifferentiated, arranged in concentric rows of fine concentric growth lines, concentric rows spaced at 0.5 to 0.75 mm anteriorly and spines spaced at 1 to 1.5 mm; anteriorly, posterior spacing of rows and spines both 0.5 to 0.75 mm; most spines erect; dorsal spines spaced more irregularly along concentric rows; dorsal valve with shallow dimples; concentric ornament of growth lines fine on ventral valve, more pronounced on dorsal valve; ventral beak fine, curved over hinge line.

Ventral interior unknown. Dorsal interior with small productellacean cardinal process, bilobed with lobes incised, shaft with alveolus; median septum low, thin, less than one-third valve length; muscle pad low, rounded; brachial ridges indistinct; endospines short, erect, arranged in concentric rows.

DISCUSSION: *Stictozoster senticosa* is atypical of the genus because of its larger size and relatively coarser and more widely spaced spines.

Coleman (1957) considered that the ventral spines are arranged quincuncially but this is because the spines are arranged in concentric rows, each being offset from the preceding row and as spines are coarser and more widely spaced than those of other species of the genus a quincuncial arrangement becomes evident. No other known species of *Stictozoster* possesses spines as coarse as those of *S. senticosa*; both *S. nielsenii* (Dunbar) and *S. licharewii* (Frebald) possess ventral spines similar to those of *S. leptus* with respect to their size and arrangement (see Archbold 1982b) and the *Stictozoster* sp. cf. *S. leptus* from Irian Jaya is even closer to the type species (Archbold *et al.* 1982).

Family OVERTONIIDAE Muir-Wood & Cooper 1960

Subfamily OVERTONIINAE Muir-Wood & Cooper 1960

DIAGNOSIS: The diagnosis provided by Muir-Wood & Cooper (1960, p. 183) is accepted.

DISCUSSION: Waterhouse (in Bamber & Waterhouse

1971) recognized the Tubersulculinae within the Overtoniidae, differentiating the subfamilial groupings on the strength of the concentric lamellae and the degree to which the ventral spines are concentrically arranged. However, several genera (e.g. *Dyschrestia*) are now known to be intermediate in these features and the subfamily groupings are not employed herein.

Genus COMUQUIA Grant 1976

TYPE SPECIES: *Comuquia modesta* Grant 1976.

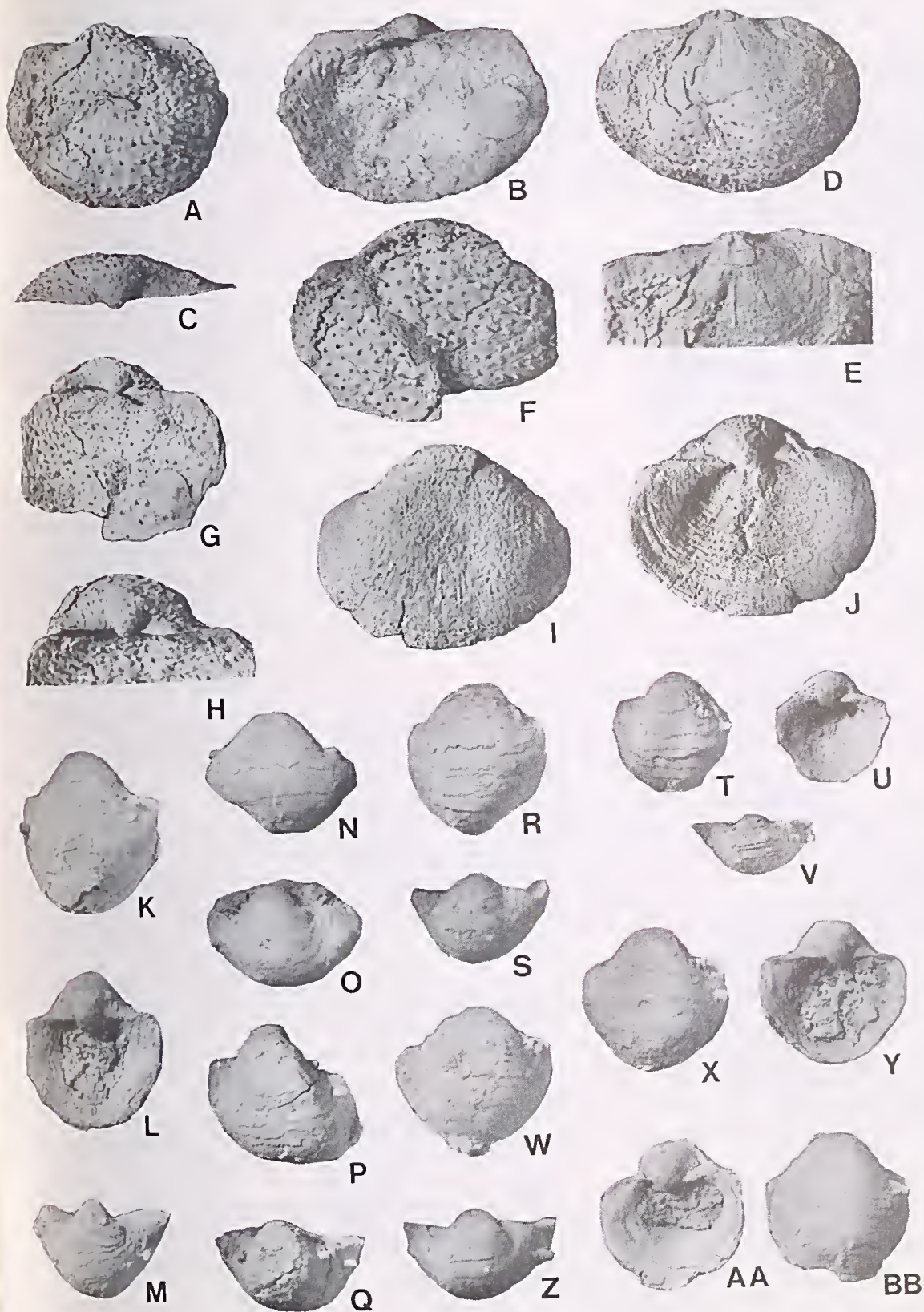
DIAGNOSIS: Small, elongate ovate; widest near midlength; growth lamellae strong, irregular; ventral spines variable in number, projecting from growth lamellae; dorsal spines few to absent; dorsal valve deeply concave; ventral valve strongly convex. Cardinal process bilobed with stout shaft; median septum thin, low; brachial ridges absent. (Revised from Grant 1976).

DISCUSSION: *Comuquia modesta* was well described by Grant (1976), however, the diagnosis of the genus requires broadening in order to include the new species *Comuquia australis* which is similar to the type species in its shell outline, concavo-convexity, growth lamellae and umbonal characteristics, but differs in possessing far fewer spines and in having a non spinose dorsal valve.

Rhythisia Cooper & Grant (1975, p. 967, pl. 311, figs 15-59) from the early Kungurian of Texas, is related to *Comuquia* yet differs in details of ventral spine pattern and in possessing distinct concentric wrinkles. *Comuquia* recalls *Scoloconcha* Gordon (1966) in details of size, convexity and ventral spinosity, but *Scoloconcha* possesses strongly developed marginal ridges and a trifid cardinal process.

Grant (1976, p. 98) considered *Comuquia* to provide an additional generic category for Permian Overtoniidae that would find wide applicability although he did not compare *C. modesta* with any other species. The group of '*Productus*' *curvirostris* Schellwein (1892, p. 26, pl. 3, figs 12-14) being both widely distributed in space and time, belongs in *Comuquia*. Originally described from possible Asselian strata of the Carnic Alps it is now known from Italy, U.S.S.R., Tien Shan, Karakorum and Thailand.

Fig. 1-A-H, *Stictozoster senticosa* (Hosking) from Callytharra Formation, Carnarvon Basin. A-C, GSWAF1/4970a1, lectotype, crushed shell in ventral, dorsal and posterior views, $\times 1.8$. D-E, GSWAF1/4970a2, crushed shell most of ventral valve missing in ventral view, $\times 1.3$ and enlargement of cardinal region, $\times 2$. F-H, GSWAF1/4970a3, crushed shell in ventral, dorsal and posterior views, $\times 1.5$, $\times 1.4$ and $\times 1.8$ respectively. I-J, ?*Lethamia obscurus* sp. nov. from Callytharra Formation, Carnarvon Basin. I-J, CPC1952, holotype, crushed shell in ventral and dorsal views, $\times 2.2$. K-Z, AA-BB, *Comuquia australis* sp. nov. from Callytharra Formation, Carnarvon Basin. K-M, GSWAF11050, holotype, shell in ventral, dorsal and posterior views, $\times 3.5$. N-O, GSWAF11191, crushed shell in ventral and posterior views, $\times 3.3$. P-Q, CPC19930A, ventral valve in ventral and posterior views, $\times 3.5$. R-S, GSWAF11190, ventral valve in ventral and posterior views, $\times 3.2$. T-V, CPC19930B, ventral valve in ventral, dorsal and posterior views, $\times 3.5$. W, GSWAF11189, ventral valve in ventral view, $\times 3.2$. X-Y, GSWAF11188, ventral valve in ventral and dorsal view, $\times 3.2$. Z, AA-BB, GSWAF11187, shell in posterior, dorsal and ventral views, $\times 3.2$.



***Comuquia australis* sp. nov.**

Fig. 1 K-Z, AA-BB

HOLOTYPE: GSWAF11050, a complete conjoined shell from the type section of the Callytharra Formation.

MATERIAL, AGE AND LOCALITY: GSWAF11050, 11187-11191, 3 conjoined shells and 3 ventral valves from the Callytharra Formation type section at Callytharra Springs. CPC19930A-19930B, 2 ventral valves, same locality, 27-32 m above base of formation; Sterlitamakian (Late Sakmarian).

MEASUREMENTS (in mm): * = holotype

Specimen number	Hinge width	Maximum width	Ventral height	Dorsal height	Thickness
GSWAF11050*	7.4	7.8	7.5	5.5	4.7
GSWAF11187	6.5	6.6	7.4	5.6	4.0
GSWAF11188	6.2	6.3	6.4	5.0	3.8
GSWAF11189	6.9	7.1	7.0	—	4.1
GSWAF11190	5.6	6.1	7.2	—	4.1
GSWAF11191	6.0	—	—	—	—
CPC19930A	5.3	6.9	5.9	—	—
CPC19930B	4.1	5.2	5.4	—	—

DIAGNOSIS: Small *Comuquia* species with distinct lamellae, sparsely spinose ventral valve.

DESCRIPTION: Subovate outline; profile an even spiral; beak prominent, strongly curved; shell widest near midlength; hinge width almost as great as maximum width; dorsal valve deeply concave, outline semicircular; growth lines visible over shell, stronger lamellose growth lines present at irregular intervals on ventral valve; ventral valve sparsely spinose, pair of spines flanking beak; row of up to three lateral spines, widely spaced; ventral spines rare, occasionally up to two on an individual growth lamella towards posterior of valve; dorsal spines apparently absent. Interior of shell unknown.

DISCUSSION: The characteristic outline and profile of this species indicate *Comuquia*; nevertheless *C. australis* is far less spinose than *C. modesta*. Bolkhovitinova and Markov's (1926) report of *Productus curvirostris* from the Sterlitamakian of the Perm region indicates a species particularly close to *C. australis* with respect to details of the beak, shell outline, size and growth lamellae. The Perm species is however more spinose than the Western Australian species although not as spinose as *C. modesta*. The group of *Productus capuloides* Stepanov (1937) possesses few spines on the ventral valve (Tschernyschew 1902, p. 271, pl. 30, figs 1, 2; pl. 53, figs 5, 6) and hence is similar to *C. australis* except for the incipient costae on the anterior of the ventral valve.

C. himalayaensis Jing & Sun (1981, p. 133, pl. 4, figs 17-26) from the early Artinskian Lasaila Limestone of

the southern Himalaya, Tibet has few ventral spines but has a less curved ventral valve than *C. australis*.

Genus LETHAMIA Waterhouse 1973

TYPE SPECIES: *Lethamia ligurritus* Waterhouse 1973.

DIAGNOSIS: The diagnosis provided by Waterhouse (1973, 1982a) is accepted.

?*Lethamia obscurus* sp. nov.

Fig. 1 I-J

1957 *Krotovia* sp. ind. A. Coleman, p. 67, pl. 9, figs 22, 23.

HOLOTYPE: CPC1952, a crushed conjoined shell from the Callytharra Formation, Pell's Range, 24 km north-east of Towrana Homestead; 36 m (i.e. 118 feet) above base of Callytharra Formation (not '180 ft above the Callytharra Formation', as in Waterhouse 1981).

MEASUREMENTS: Maximum width 18.5 mm; hinge width 13 mm; height of dorsal valve 13 mm estimate.

DESCRIPTION: Shell with transversely oval outline; non-geniculate; ventral umbo small, curving over hinge; greatest width anterior of hinge at about shell mid length; convexo-concavity of shell moderate, visceral cavity thin. Ventral valve covered in spines—very fine of uniform size; spines arranged subquincuncially over most of valve, on average 0.75 mm apart and 0.25 mm wide at their base; on anterior of valve spines in concentric rows; rows widely spaced, 1.5-2.0 mm apart. Fine concentric lirae on ventral valve. Dorsal exterior with fine spines and concentric lirae; spines of similar size and arrangement to those of ventral valve. No dorsal dimples. Shell interior unknown.

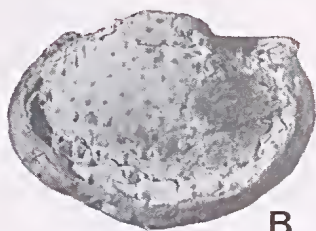
DISCUSSION: Coleman (1957) recognised that this shell represented a distinctive species from Western Australia. Despite additional extensive collections from the Callytharra Formation having been made by Dr G. A. Thomas, University of Melbourne and geologists of the Geological Survey of Western Australia no comparable specimens have been collected. Rather than leave the specimen in open nomenclature it appears advisable to formally name it to highlight its distinctive external morphology. The shell gives no indication of being a sport (e.g. aberrant growth patterns or outline) and is readily distinguishable from all other species.

?*Lethamia obscurus* is closest to *Lethamia* in that it lacks dimples on the dorsal exterior, lacks distinct concentric lamellae and has fine dorsal spines but generic certainty cannot be verified without details of the dorsal interior. Waterhouse (1981, p. 74) and Grant (1976) sug-

Fig. 2-A-Q, *Dyschrestia micracantha* (Hosking) from Callytharra Formation, Carnarvon Basin. A-B, GSWAF1/4970b2, crushed shell in dorsal and ventral views, $\times 2.2$. C-D, GSWAF1/4970b1, lectotype, crushed shell in dorsal and ventral views, $\times 2.2$. E-F, MUGDF6002, incomplete shell in ventral and dorsal views, $\times 1.8$ and $\times 2$ respectively. G-I, MUGDF6004, crushed shell in dorsal, ventral and posterior views, $\times 2$. J-L, MUGDF6001, crushed shell in ventral, dorsal and anterior views, $\times 1.8$, $\times 2$ and $\times 1.8$ respectively. M-O, CPC1954, dorsal valve in dorsal, ventral and posterior views, $\times 1.6$, $\times 1.8$ and $\times 2.2$ respectively. P-Q, MUGDF6003, crushed shell in dorsal and ventral view, $\times 2$.



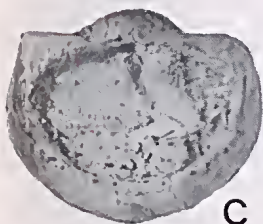
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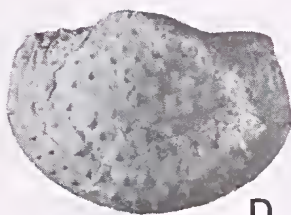
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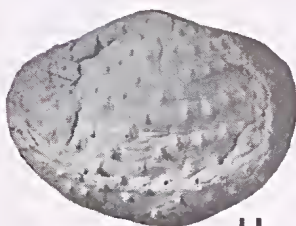
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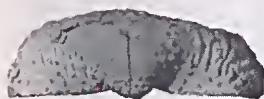
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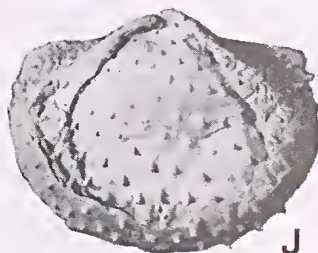
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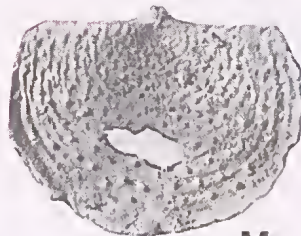
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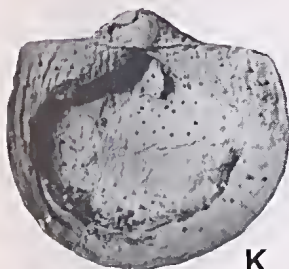
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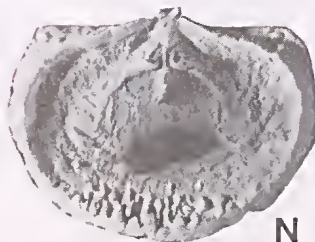
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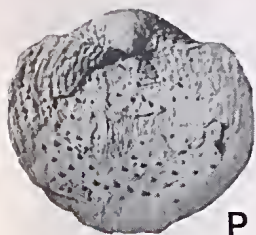
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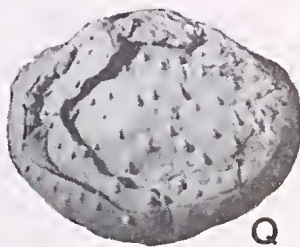
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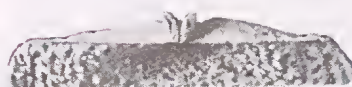
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gested that the specimen may belong to *Stictozoster* but that genus possesses distinct dimples and a stronger development of concentric lamellae on the dorsal exterior, also, when the spines are fine on *Stictozoster*, they are dense with the concentric rows being close together. The generic diagnosis of *Stictozoster* has already been enlarged to incorporate *S. senticosa*.

Genus *DYSCHRESTIA* Grant 1976

TYPE SPECIES: *Dyschrestia spodia* Grant 1976.

DIAGNOSIS: The diagnosis provided by Grant (1976) is accepted with the exception that the dorsal interior may possess a distinct marginal ridge, a distinct median septum with a raised anterior termination and raised adductor muscle scars.

DISCUSSION: Grant (1976) compared *Dyschrestia* with several other genera including *Grandaurispina* Muir-Wood & Cooper 1960 and *Holotricharina* Cooper & Grant 1975 of the Linoproductidae which are externally somewhat similar to *Dyschrestia*. Grant noted that *Krotovia* Fredericks 1928 was nearest to *Dyschrestia* in general outline and profile and may well have been a progenitor. *Krotovia* was distinguished from *Dyschrestia* by the more even distribution of spines not tending to be concentrically banded by the presence of growth lamellae, the larger number of dorsal spines and greater development of radial rather than concentric wrinkling due to some species of *Krotovia* having costae bearing spines. The reassessment of *Krotovia* by Brunton (1966) indicates that species of *Krotovia* may at times possess a distinct concentric ornament and spines arranged in concentric rows. *Dyschrestia* however, possesses coarser, rather more spaced out ventral spines than *Krotovia* and a more strongly developed interior dorsal median septum. The dorsal septum is strongly developed in both Western Australian species although weakly developed in the type species from Thailand, but, figured Thai dorsal valves appear juvenile when compared with Western Australian specimens and this may explain the discrepancy.

Jakutella Abramov (1970, p. 119, pl. 4, figs 1-17) possesses rather pronounced wrinkling—almost true concentric rugae—and a stronger concavo-convexity than *Dyschrestia*. The dorsal valve of *Jakutella* is strongly dimpled, like *Krotovia* and carries few spines. The anterior ventral spines of *Jakutella* bear short costae or radial ridges.

Lanispustula Klets 1983 is of similar size to *Dyschrestia* but possesses elongate spine ridges, internal striations over the dorsal visceral disc and larger brachial ridges than *Dyschrestia*. *Lethamia*, well illustrated by

Waterhouse (1982a), is much larger than *Dyschrestia*, and although *Lethamia* possesses a dorsal septum and raised anterior adductor scars like those of *Dyschrestia* it lacks the pronounced dorsal marginal ridge of *Dyschrestia*. Spines are much finer on *Lethamia* than on *Dyschrestia*.

Dyschrestia micracantha (Hosking 1933)

Fig. 2A-O

1933 *Pustula micracantha* Hosking, p. 49, pl. 4, fig. 4a, b.

1937 *Pustula micracantha* Hosking; Raggatt and Fletcher. *Rec. Aust. Mus.*, 20: 176.

1943 *Krotovia micracantha* (Hosking); Prendergast, p. 30.

1957 *Krotovia micracantha* (Hosking); Coleman, p. 61, pl. 7, figs 16-18; pl. 9, figs 20, 21.

LECTOTYPE: GSWA 1/4970b1; Hosking, 1933, pl. 4, figs 4a, b. Chosen by Coleman (1957, p. 61).

MATERIAL, AGE AND LOCALITIES: GSWA1/4970b1 and 2, 2 conjoined crushed shells, from creek, 1.25 km west of Callytharra Springs, Wooramel River, Callytharra Formation, Carnarvon Basin. MUGDF6001-F6003, 3 conjoined crushed shells, from locality P477, measured section of type section of Callytharra Formation, Callytharra Springs, 24 m above base, collector Dr G. A. Thomas. MUGDF6004, a crushed conjoined shell, from Locality P498, as for P477, 34-38 m above base of formation. CPC1954, Pell's Range, Carnarvon Basin, 24 km northeast of Towrana Homestead, 36 m above base of Callytharra Formation; Sterlitamakian (Late Sakmarian).

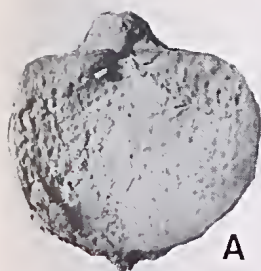
MEASUREMENTS (in mm): * = lectotype

Specimen number	Hinge width	Maximum width	Ventral height	Dorsal height
GSWA1/4970b1*	14.6	17.2	13.5	12.0
GSWA1/4970b2	13.2	17.3	13.8	12.0
MUGDF6001	18.7	21.1	17.9	15.5
MUGDF6002	16.5	20.0	—	15.2
MUGDF6003	14.5	18.5	15.8	13.4
MUGDF6004	15.5	20.8	17.0	13.5
CPC1954	15.5	19.5	—	15.6

DIAGNOSIS: Large sized *Dyschrestia* distinguished by high dorsal median septum which is raised anteriorly, smaller beak and less crowded spines on the ventral valve.

DESCRIPTION: Outline transversely subelliptical; non geniculate; ventral umbo small, pointed, slightly curving over hinge line; greatest width anterior of the hinge at about midlength of shell; ventral valve moderately con-

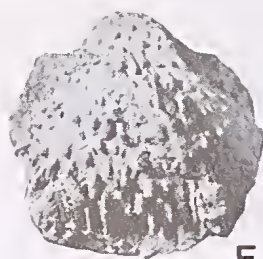
Fig. 3-A-O, *Dyschrestia colemani* sp. nov. from Wandagee Formation, Carnarvon Basin. A-E, AMF38446, holotype, shell in dorsal, ventral, posterior, anterior and lateral views, $\times 2.2$. F-I, AMF38443, ventral valve in ventral, left lateral, right lateral and posterior views, $\times 2$. J-K, AMF37579, shell with ventral valve cut away in ventral and postero-ventral views, $\times 2.2$. L-M, AMF38442, ventral valve in ventral and posterior views, $\times 2$. N, AMF37725, ventral valve in ventral view, $\times 1.6$. O, AMF37518, decorticated dorsal valve interior, $\times 2$. P, AMF37582, dorsal valve external mould with thin portions of dorsal valve remaining, $\times 2$. Q, AMF38443, ventral valve in dorsal view, $\times 2.6$.



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B



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E



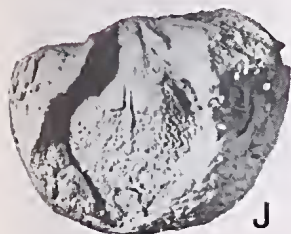
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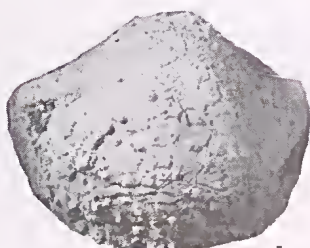
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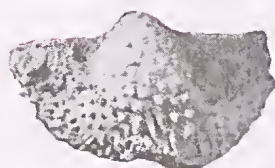
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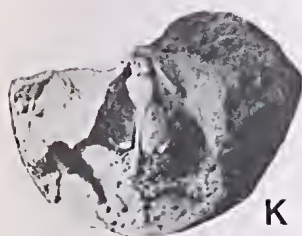
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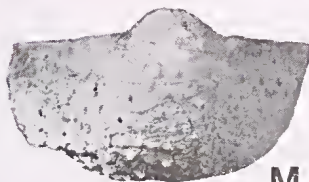
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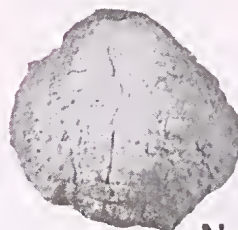
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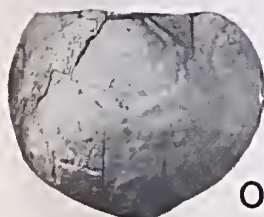
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P



Q

vex; dorsal valve moderately concave; visceral cavity thin. Ventral valve covered in spines, lateral spines not distinct from visceral spines, spines arranged in concentric rows spaced usually at 1.5 mm to 2 mm intervals on anterior half of valve; successive concentric rows impart a quincuncial arrangement to the spines; dorsal spines finer than ventral spines, arranged concentrically over valve except for ears where arrangement is in two radial rows. Growth lines and delicate concentric ridges developed on ventral valve, lower and broader anteriorly; similar more pronounced concentric ornament on dorsal valve.

Ventral interior unknown. Dorsal interior with short bilobed cardinal process; muscle pads thickened and raised anteriorly; median septum arising between muscle pads, low posteriorly, narrow and high anteriorly, anterior extremely high, just under half valve length; brachial ridges weak, about two-thirds of valve length; remainder of valve covered by endospines, more pronounced at anterior extremity of valve. Pronounced marginal ridge present.

DISCUSSION: Examination of specimens not available to Hosking (1933), Prendergast (1943) or Coleman (1957) confirms that the ventral beak overhangs the hinge, that the species can be larger than previously thought and that hinge width is significantly less than maximum width of mature shells.

The species is differentiated from *D. colemani* sp. nov. and *D. spodia* by its strongly developed dorsal interior structures, notably the marginal ridge and the median septum that terminates anteriorly as a pronounced raised structure. *D. micracantha* is also distinguished by its ventral spine characteristics and a stronger development of the concentric ornament than that of the two younger species.

Dyschrestia colemani sp. nov.

Fig. 3A-Q

1943 *Krotovia spinulosa* (Sowerby); Prendergast, p. 30, pl. 4, figs 11-13.

1957 *Krotovia spinulosa* (Sowerby); Coleman, p. 65, pl. 7, figs 19-24.

ETYMOLOGY: For Dr P. J. Coleman, who has added extensively to the knowledge of Western Australian Permian Productidina.

HOLOTYPE: AMF38446, a complete conjoined shell, from the Wandagee Formation.

MATERIAL, AGE AND LOCALITIES: Nine specimens in various states of preservation. AMF37579, 403 m west of shale outcrop, north bank of Minilya River, Wandagee Formation; AMF38442, 38443, 38446 Wandagee Station, Minilya River, Wandagee Formation; AMF37563, 37564, 37578, 37582, bank of Minilya River, North West Division, Wandagee Formation; AMF37725, Wandagee Station, Minilya River, Wandagee Formation; Late Baigendzinian (Late Artinskian).

MEASUREMENTS (in mm): * = holotype

Specimen number	Hinge width	Maximum width	Ventral height	Dorsal height	Thickness
AMF38446*	12.8	17.3	15.5	13.5	8.1
AMF38443	12.0	16.5	16.0	13.2	8.8
AMF37725	—	16.1	15.6	—	—
AMF38442	15.5	19.0e	17.0+	—	—
AMF37578	—	18.0e	—	15.0	—
AMF37582	10.8+	16.0	—	12.3	—

DIAGNOSIS: Average sized *Dyschrestia* distinguished by distinctly developed median septum and muscle pads. Externally close to type species of the genus.

DESCRIPTION: Outline transversely subelliptical to circular; non geniculate; ventral umbo small, pointed, distinct; greatest width anterior of the hinge at about midlength of shell; dorsal valve distinctly concave; spines closely spaced on both valves, finer on dorsal valve; ventral lateral spines in single row in juvenile stages, double row in adult stages; remainder of ventral spines as coarse as lateral spines or at times finer; dorsal spines normally broken leaving fine pustulose bases, arranged quincuncially on most of valve except for ears where arrangement is in two distinct radial rows; growth lines poorly expressed on ventral valve, stronger on dorsal valve.

Ventral interior unknown. Dorsal interior with short bilobed cardinal process; muscle pads thickened anteriorly; median septum arising between muscle pads, low posteriorly, narrow and high anteriorly, anterior extremity low, about half valve length; brachial ridges weak, in posterior of valve, enclosing smooth floor; remainder of valve covered with endospines.

DISCUSSION: *Dyschrestia colemani* is similar to *Dyschrestia spodia* in many respects. The Thai species, however, at times is widest at the hinge (Grant 1976, pl. 22, figs 19, 20) and possesses ventral spines arranged in distinctly concentric rows (Grant 1976, pl. 22, figs 9, 29) both unlike the present species. The dorsal median septum of *D. colemani* is more strongly developed and longer than that of *D. spodia*. Comparisons with *D. micracantha* are under that species heading. The specimen from Bitauini, Timor attributed to *Productus opuntia* by Broili (1916, pl. 3, fig. 10) may be related to the Western Australian species judging from gross shell form and ventral spine pattern.

Waterhouse (1981, p. 76) considered that *D. colemani* specimens were particularly close to *Lethamia*, whereas he (1982a, p. 43) noted that the Western Australian shells are smaller, with a higher ventral umbo, more angular cardinal extremities and relatively coarser spines. Spines on *D. colemani* are certainly much coarser than on *Lethamia* and the Western Australian species possesses distinctive external dorsal dimples and distinctive dorsal adductor muscle pads. The specimen recorded by Coleman (1957) from the Cundlego Formation is also numbered T42 which is a locality of Dr C. Teichert's from the Wandagee Formation and hence the occurrence of the species from the Cundlego Formation cannot be confirmed.



Fig. 4-A-G, *Dyschrestia* sp. from Coolkilya Greywacke, Carnarvon Basin. A-E, UWA28145b, ventral valve in ventral, anterior, posterior, dorsal and lateral views, $\times 2.5$. F-G, UWA28145a, ventral valve in ventral and lateral views, $\times 2.5$.

Dyschrestia sp.

Fig. 4

1957 *Krotovia spinulosa* (Sowerby); Coleman (*partim.*), p. 65, non. illus.

MATERIAL, LOCALITY AND AGE: 2 incomplete ventral valves, UWA 28145a and 28145b, a few hundred yards (metres) south east of Wandagee Hill, Mungadan Pad-dock, Wandagee Station (collected by Dr C. Teichert). Coolkilya Greywacke; middle Kungurian.

MEASUREMENTS (in mm): e = estimate

Specimen number	Hinge width	Maximum width	Ventral height
UWA28145a	11.5e	15.9	14.8
UWA28145b	—	15.1 +	13.6

DESCRIPTION: Circular outline; ventral valve strongly enrolled, ventral umbo small, pointed; greatest width at about midlength of shell; spines closely spaced on ventral valve (1.0 to 1.5 mm), arranged in distinct concentric rows anteriorly; spines fine with fine, circular or only slightly elongated spine bases; lateral spines in single row and, judging from bases, fine and undifferentiated from remainder of spines; ventral growth lines very weakly developed.

DISCUSSION: Although inadequate for detailed description the two specimens indicate a distinct species, differentiated from other Western Australian species by means of a highly convex ventral valve with an ornament of fine spines and fine spine bases. Details of the shell outline and the arrangement of the ventral spines may also prove specifically distinctive.

ACKNOWLEDGEMENTS

I thank Dr J. M. Dickens, Bureau of Mineral Resources, Geology and Geophysics; Dr A. E. Cockbain, Geological Survey of Western Australia; Dr A. Ritchie, the Australian Museum and Dr G. A. Thomas, University of Melbourne, for the loan of specimens in their care. Dr G. A. Thomas read an earlier version of the paper. Isabel Munro typed the manuscript and Linda Archbold assisted with photography.

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DESCRIPTION OF A NEW SPECIES OF *GADOPSIS* (PISCES: GADOPSIDAE) FROM VICTORIA

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ABSTRACT: Analysis of radiographs revealed a new species of *Gadopsis* from Victoria. The diagnostic character distinguishing the new species from *G. marmoratus*, the only described species, exhibits a range of values which does not overlap with that seen in *G. marmoratus*, even when sympatric with it. A separate species of *Gadopsis* from Tasmania, proposed by Parrish (1966), was found to be invalid when the same diagnostic characters as used by Parrish (1966) were examined.

The Gadopsidae is the only family of Australia's relatively depauperate freshwater fish assemblage which is both endemic to southeastern Australia and strictly confined to fresh water. Frankenberg (1974) considered the family to be a primary freshwater fish family, *sensu* Darlington (1957), although this view was not supported by McDowall (1981). Attempts to trace the relationships of the family have rarely reached common conclusions (see Thomson & Baldwin 1983, for a review).

Gadopsis marmoratus Richardson, the only described species, is variable in colouration and morphology, and detailed analysis of this variation may reveal a species complex. A separate species of *Gadopsis* from Tasmania was proposed by Parrish (1966) on the basis of morphological differences. His 'species' has frequently appeared in the literature under the proposed name without a formal description having been published. Despite a recommendation by Jackson and Llewellyn (1980) against its use, this *nomen nudum* continues to appear in publications (Cadwallader & Backhouse 1983), adding to the taxonomic confusion surrounding the group.

Preliminary sampling of *G. marmoratus* throughout its range revealed that specimens from King River and King Parrot Creek had distinct white margins to the outer edge of the dorsal, anal and caudal fins. The significance of this was investigated by comparing the morphometric and meristic variation within these populations with *G. marmoratus* from elsewhere in its range, in Victoria and Tasmania. Analysis of meristic variation (Table 1) revealed a new species of *Gadopsis* (described below) in King River and King Parrot Creek. The new species shares its geographic range with *G. marmoratus*, and is occasionally found in the same stream, although there appears to be a degree of habitat partitioning between them. The analysis did not support recognition of a separate Tasmanian species (Table 2).

MATERIALS AND METHODS

Live fish were collected with a portable D.C. electroshocker from shallow pools in the King River and King Parrot Creek in northeastern Victoria. Specimens were examined by using the techniques of Hubbs and Lagler (1947), except that fin ray counts include all rays, whether branched or unbranched. Pectoral ray counts were obtained by removing the fleshy skin covering the

base of the fin, to expose the rays at their origin. All other counts were obtained from radiographs. Several specimens were cleared and stained following the technique of Mahoney (1973), in order to examine dentition. Type material has been deposited in the Museum of Victoria (NMV), and the Australian Museum, Sydney (AMS).

Collections of *G. marmoratus* used in the study are as follows (numbers of individuals at each site are indicated in brackets; * indicates the collections used in Table 2): Stony Creek, 3 km upstream from junction with King River, Cheshunt, Victoria (4), 31 Oct. 1983, A. Sanger, S. Fisher and J. Rose; Kumbada Creek, 3 km upstream from junction with Stony Creek, Cheshunt, Victoria (6), 31 Oct. 1983, A. Sanger, S. Fisher and J. Rose; Kumbada Creek, 3 km upstream from junction with Stony Creek, Cheshunt, Victoria (20), 12 Dec. 1979, A. Sanger and P. Burrowes; Hurdle Creek, Bobinwarrah, Victoria (12), 6 Aug. 1979, A. Sanger and G. Gibb; Hurdle Creek, Bobinwarrah, Victoria (1), 19 Oct. 1983, A. Sanger; Chum Creek, Healesville, Victoria (15)*, 20 Feb 1981, A. Sanger; Wonnongatta River, 1 km downstream from junction with Hummfray River, near Dargo, Victoria (20)*, 21 Apr. 1980, A. Sanger and P. Burrowes; Elizabeth Creek, 2 km north of Allambee South, Victoria (19)*, 4 Feb. 1980, A. Sanger and D. Brock; Glenelg River, Victoria Valley Road, the Grampians, Victoria (7), 28 May 1982, A. Sanger and P. Murphy; Minnow River, near Lower Beulah, Tasmania (10)*, 6 Sept. 1983, R. Sloane; Lake River, 24 km south of Cressy, Tasmania (10)*, 20 Oct. 1982, A. Sanger.

SYSTEMATICS

Class PISCES
Family GADOPSIDAE
Genus *Gadopsis*
Gadopsis bispinosus sp. nov.

Fig. 1

ETYMOLOGY:

The species is named after the number of spines in the dorsal fin.

MATERIAL: Holotype, NMVA3281, female, 20.0 cm TL, coll. 15 Dec. 1979 on West branch of King River, 2 km upstream from junction with east branch of King River,



Fig. 1—*Gadopsis bispinosus*, sp. nov.; King Parrot Creek, 201 mm TL.

near Cheshunt, Victoria, 36°52'S, 146°23'E. Paratypes, NMVA3282, 5 specimens, coll. 15.xii.1979, A. Sanger and P. Burrowes, type locality. AMS I.24351-001, 6 specimens, coll. 15 Dec. 1979, A. Sanger and P. Burrowes, type locality. Other material examined, with numbers of specimens noted in brackets, King River (type locality) (8), 15 Dec. 1979, A. Sanger and P. Burrowes; King River (type locality) (6), 31 Oct. 1983, A. Sanger, S. Fisher and J. Rose; Stony Creek, 3 km upstream from junction with King River, Cheshunt, Victoria (3), 31 Oct. 1983, A. Sanger, S. Fisher and J. Rose; King Parrot Creek, 8 km downstream from Kinglake West, Victoria (13), 3 Nov. 1979, A. Sanger and C. Proctor; King Parrot Creek, 8 km downstream from Kinglake West, Victoria (7), 20 Oct. 1980, A. Sanger.

DIAGNOSIS: Differs from *G. marmoratus* in having two, or rarely one or three, spines in the dorsal fin (Table 1, Fig. 2) and prominent white fringe on the dorsal, anal and caudal fins. *G. marmoratus* has between six and thirteen spines in the dorsal fin (Table 1, Fig. 2), and lacks a prominent white fringe on the fins.

DESCRIPTION: (Holotypic values in parentheses.) A small to medium sized species; body narrow (width=0.13 of Standard Length (SL)), shallow (depth=0.19 of SL) and slightly compressed. Head narrow and slightly elongated (length=0.24 of SL); snout short (length=0.24 of Head Length (HL)); eye moderate (maximum width=0.19 of HL), inserted in upper half of head; suborbital depth large (0.53 of head depth at orbit); interorbital width narrow (width=0.21 of HL). Jaws long (length=0.40 of HL); with upper jaw extending to below the posterior half of the eye. Lips fleshy with upper overhanging lower. Teeth numerous; in premaxilla, an outer row of large conical teeth, within which there is a band of minute cardiform teeth becoming narrower towards posterior articulation; dentary similar to premaxilla; palatines and vomer bearing numerous small cardiform teeth. Two prominent rows of laterosensory pores on head; one along upper jaw margin extending upwards to behind eye; the other following lower jaw margin, extending along anterior margin of preoperculum and back towards opercular spine. Numerous smaller pores on head. Two prominent nostrils; one, halfway along snout, with fleshy tubular opening; the other, just in front of the eye, simple.

Pelvic reduced to a single fleshy bifid ray inserted jugularly (insertion point = 0.64 in HL). Branchiostegals seven; opercular spine single, with subopercular flap. Pectorals inserted laterally, below opercular spine (insertion point = 0.94 in HL), rounded, moderate in size (maximum ray length = 0.56 in HL), with fifteen to eighteen rays (16).

A single long dorsal fin (length = 0.62 of SL), inserted posterior to the level of the pectorals (insertion point = 0.28 of SL), bearing two, rarely one or three, weakly-calcified, slender spines and thirty-five to thirty-eight rays (11, 37). Anal fin long (length = 0.27 of SL), originating about half way along body (insertion point = 0.59 of SL), bearing three, strongly-calcified, stout, spines and seventeen to twenty rays (11 (one vestigial), 20). Anal and dorsal fins, when adpressed, not reaching caudal fin. Caudal fin rounded, of about thirty rays (29), half of which are branched (15). Caudal peduncle shallow (depth = 0.09 of SL) and compressed.

Lateral line, of about forty-eight tubercles, originating just above opercular spine, curving dorsally to follow dorsal profile for about the first five-eighths of the dorsal fin before descending gradually to follow midline for length of caudal peduncle.

Vertebrae forty-six to forty-nine (48), twenty-five to twenty-nine of which are caudal (27).

COLOURATION: Colouration variable, consisting typically of two uneven rows of dark brown blotches running entire length of body, extending onto dorsal and caudal fins. A third row of blotches often present, extending onto posterior half of anal fin. Brown blotches separated by paler areas; ventral surface uniformly pale from pelvic origin to anal origin. Outer edge of dorsal, anal and caudal fins white, often bordered on inner margin by an intense dark stripe. Fin rays in dorsal, anal and caudal often bright yellow in live specimens. Colour pattern more distinct in juveniles, often being obscured by intensified pigmentation in older specimens. In life, able to intensify or subdue base colouration to suit surroundings.

LIFE HISTORY: Essentially as described by Jackson (1978) and Cadwallader and Backhouse (1983), for *G. marmoratus*. Egg number varies with size of female, a 20.7 cm TL female bearing up to 350 mature eggs, 3.6 mm in diameter. Maximum TL observed, 25.7 cm, weight, 130 gm. Scales indicate fish of this size to be in their fifth year. Fish less than 10 cm TL normally juvenile (Sanger, unpubl.).

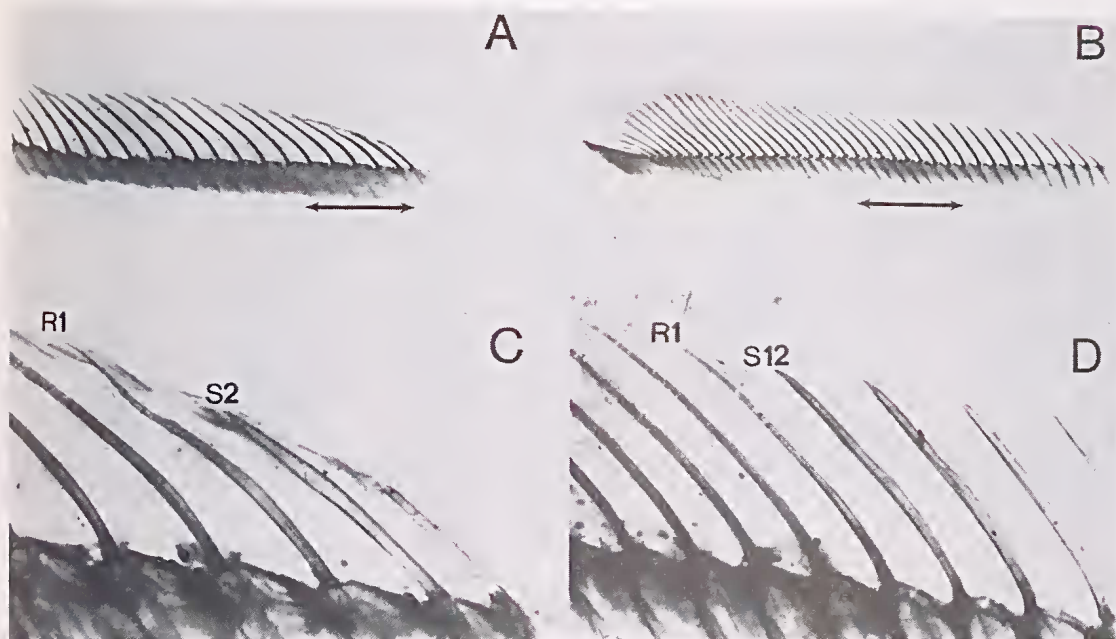


Fig. 2—Cleared and stained dorsal fins of: A, *Gadopsis bispinosus*, anterior section. B, *G. marmoratus*, entire fin. C, *G. bispinosus*, enlargement of arrowed section of A, S2 is the second spine, R1 is the first ray (note jointed appearance of rays). D, *G. marmoratus*, enlargement of arrowed section of B, S12 is the twelfth spine, R1 as above.

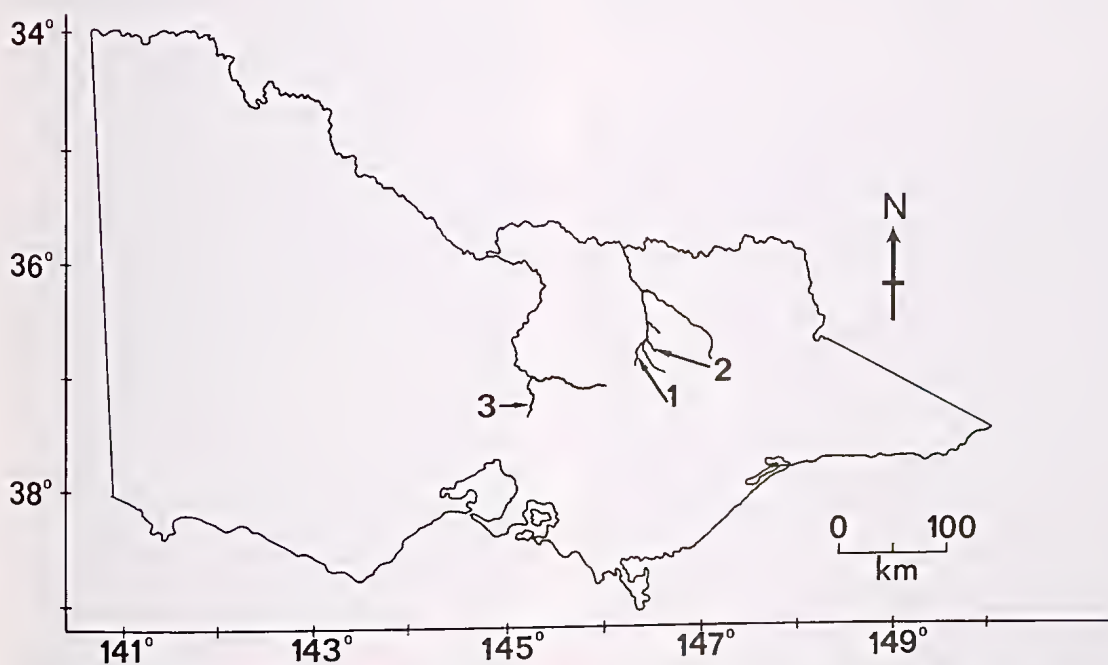


Fig. 3—Known distribution of *G. bispinosus*. 1, King River, west branch, type locality; 2, Stony Creek, near Cheshunt; 3, King Parrot Creek, near Kinglake West.

TABLE 1

MORPHOMETRIC AND MERISTIC VARIATION IN TWO SPECIES OF *Gadopsis* BASED ON THE MATERIAL EXAMINED.

Morphometric measurements other than total length are expressed as percentages of the total length. (Note the non-overlapping ranges of dorsal spine and dorsal ray counts, used to justify species separation.)

	<i>Gadopsis bispinosus</i>			<i>G. marmoratus</i>		
	Range	Mean	Std. dev.	Range	Mean	Std. dev.
Total length (TL) (cm)	116-251	173.9	34.94	101-354	207.3	62.85
Head length	17.8-22.2	19.9	1.011	18.9-25.1	22.5	1.331
Snout length	4.7-6.4	5.4	0.443	4.7-7.0	6.0	0.443
Upper jaw length	7.4-9.6	8.3	0.535	3.8-10.3	8.7	0.893
Interorbital width	3.8-5.1	4.4	0.254	4.1-6.9	5.8	0.518
Body width	9.0-12.9	10.6	1.053	9.6-14.8	12.3	1.308
Body depth	13.0-18.4	15.7	1.353	15.0-25.1	19.3	1.733
Caudal fin length	15.0-20.0	18.2	1.052	14.7-21.5	18.7	1.124
Caudal peduncle depth	6.1-7.7	6.9	0.395	6.6-9.7	8.3	0.848
Dorsal fin depth	4.3-8.0	6.1	0.871	4.6-9.7	7.4	0.892
Dorsal spines	1-3	2.0	0.243	6-13	10.9	1.416
Dorsal rays	35-38	36.9	0.772	22-31	26.6	1.447
Pectoral rays	15-18	16.5	0.701	15-19	17.7	1.402
Anal spines	3	3	0	2-4	3.1	0.378
Anal rays	17-20	18.8	0.690	16-20	18.1	1.078
Total caudal rays	28-31	29.3	0.802	27-35	30.1	1.825
Branched caudal rays	13-16	15.0	0.594	15-18	16.4	0.950
Total vertebrae	46-49	48.3	0.780	40-50	46.5	1.726
Caudal vertebrae	25-29	27.7	0.867	24-28	26.5	0.937
Number of fish measured	Morphometrics 38; Meristics 35			Morphometrics 79; Meristics 103		

DISTRIBUTION AND ABUNDANCE: Collected from the upper reaches of the King River and its tributaries, and from the upper reaches of the King Parrot Creek (Fig. 3). Common in both these streams, which have similar rocky beds and cool, clear water. Likely to be found in many of the northeastern Victorian streams which also have these characteristics.

DISCUSSION: Parrish (1966) discussed variation in dorsal spine number in populations of *G. marmoratus* from several localities throughout its geographic range. He recognised that samples from western Victoria had fewer dorsal spines than those from the rest of Victoria and from Tasmania. A sample from Violet Creek, a tributary of the Glenelg River, Victoria, showed a range of seven to nine (mean=8.2). The sample from the Glenelg River included in this study, with a range of six to nine (mean=7.6), conforms with these observations. These values, while low, partially overlap with the ranges seen for populations from other areas and, on that basis, do not warrant the erection of a separate western Victorian taxon. *G. bispinosus*, on the other hand, exhibits a non-overlapping range in this character. This is not a case of clinal variation, since *G. bispinosus* is found in sympatry with *G. marmoratus*. *G. marmoratus*, from Stony Creek, which is within 10 km of the type locality for *G. bispinosus*, exhibit a dorsal spine range of nine to eleven (mean 10.4), well within the normal range for *G. marmoratus*. The sample sites used by Parrish did not include any which were likely to have contained *G. bispinosus*, namely, clear, cool, rocky-bottomed streams in northeastern Victoria.

G. bispinosus, although sympatric with *G. marmoratus* in the upper King River, is apparently better adapted to life in clear, rocky-bottomed streams, and *G. marmoratus* to slower flowing, more turbid, soft-bottomed streams north of the Great Dividing Range. It should be noted that *G. marmoratus* occur in clear, rocky-bottomed mountain streams south of the Great Dividing Range. This distribution is analogous to that of the percichthyid genus *Maccullochella*, also found in this area (Cadwallader & Backhouse 1983). The Trout Cod, *M. macquariensis*, although rare now, was typically found in the cooler upper reaches of streams throughout the Murray-Darling system, whereas the Murray Cod, *M. peeli*, is widespread throughout the lower reaches of these streams becoming scarcer towards the headwaters. There is some evidence that these two species form interspecific hybrids in a population inhabiting Cataract Dam on the Nepean River, New South Wales (Cadwallader & Backhouse 1983). No evidence of interspecific hybrids between *G. bispinosus* and *G. marmoratus* was detected in the present study.

Whilst the past distribution of *G. bispinosus* is unknown its local abundance suggests that it may not be suffering the same reduction in numbers as has been seen in the Trout Cod. Although inhabiting trout angling waters and preyed upon by brown trout, *Salmo trutta* (Sanger, unpub.), *G. bispinosus* is the most abundant member of the fish fauna at the localities shown in Figure 3. Although three localities are hardly adequate to form an opinion, the preliminary indications are that *G. bispinosus* should not be considered a rare or en-

TABLE 2

MERISTIC VARIATION IN POPULATIONS OF *G. marmoratus* FROM TASMANIA AND FROM SOUTH OF THE GREAT DIVIDING RANGE IN VICTORIA.Based on the samples marked with an * in the lists of material. 't' value represents the result of a two-tailed Student's t-test for difference between means. Significance level, n.s. - $p > 0.01$.

	Tasmania			t	Southern Victoria		
	Range	Mean	Std. dev.		Range	Mean	Std. dev.
Dorsal spines	11-13	11.9	0.641	2.09 n.s.	9-13	11.4	0.900
Dorsal rays	24-28	26.3	1.031	1.35 n.s.	24-31	26.8	1.559
Pectoral rays	17-19	18.6	0.605	1.23 n.s.	17-19	18.7	0.499
Anal spines	3	3	0	0.96 n.s.	2-3	3.0	0.211
Anal rays	17-20	18.6	0.681	0.51 n.s.	16-20	18.7	0.795
Total caudal rays	29-33	30.5	1.100	2.60 n.s.	27-35	31.4	1.421
Branched caudal rays	16-18	16.9	0.447	0.69 n.s.	15-18	17.0	0.571
Total vertebrae	45-49	47.4	0.940	1.25 n.s.	42-50	47.5	1.170
Caudal vertebrae	25-28	26.6	0.883	0.49 n.s.	25-28	26.9	0.734
Number of fish measured		20				44	

dangered species, or, at this stage, be afforded any protection distinct from that given *G. marmoratus*.

Table 2 clearly demonstrates that the Tasmanian populations sampled belong to *G. marmoratus*. Parrish (1966) proposed a separate species on the basis of a larger number of branched caudal rays, pectoral rays, vertebrae, and lateral line pores. The first three of these characters, when examined in the present study, were not significantly different than in populations of *G. marmoratus* from south of the Great Dividing Range in Victoria, and in fact almost complete overlap in the range of values is seen. These observations should end reference to an undescribed, and apparently non-existent, Tasmanian species. A future paper will examine the question of variation within *G. marmoratus* in more detail, with reference to biochemical information as well as morphological data.

ACKNOWLEDGEMENTS

I thank Martin Gomon, Museum of Victoria, for access to X-ray facilities, Murray Littlejohn and Graeme Watson for critically reading earlier drafts of the manuscript, and the many friends and colleagues who assisted in the field. The Australian Museum Trust, and the Victorian Fisheries and Wildlife Division, contributed funds towards meeting field work costs.

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GEOMORPHOLOGY OF THE LAKE OMEO BASIN, VICTORIA

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ABSTRACT: Lake Omeo is a relic of a more extensive lake formed when a basalt flow, dated as Upper Pliocene in age, dammed the flow of Morass Creek. This larger lake is referred to as Lake Morass. Downfaulting of part of the Lake Omeo basin and upthrow of a narrow horst between the Morass Creek and Minute Creek catchments probably occurred at about the same time or later. Sedimentation of the natural overflow gap of the Lake Omeo basin during the existence of Lake Morass resulted in the basin becoming isolated from Morass Creek as the basalt flow was incised. Clay sediments over 40 m thick were deposited in the downfaulted part of the basin. Two clay lunettes to the southeast of the present lake, and material of fluvial and lacustrine origin provide evidence for alternation between wet periods when high water levels prevailed and dry periods with low water levels during which lunette building occurred. The evidence has been interpreted as indicating major changes in climate in the history of the lake. At least three lunette building phases are proposed, separated by periods of high lake levels. A palaeosol buried beneath a layer of clay of lacustrine origin is ascribed an Upper Pliocene origin.

In this paper a number of unusual features associated with the Lake Omeo basin are described and their origins are examined. An interpretation of the geomorphic history of the area and its significance in relation to Pleistocene environments in this region is proposed.

Lake Omeo, a small ephemeral lake near Benambra in the northeastern highlands of Victoria (Fig. 1), is the focus of an internal drainage basin of about 57 km². The area has a general elevation of about 750 m above sea level, but because of an extensive rain shadow produced by the Mt. Hotham-Mt. Bogong highlands to the west, the average annual rainfall is only about 630 mm. The water level in the lake fluctuates considerably, both seasonally and from year to year. It is often dry for long periods. It reached its highest level in recent times in 1956. No permanent record of lake levels is kept. The 1956 level was apparently slightly higher than the level determined during level surveys in 1960 (Fig. 2) and shown in Figs 7 and 8. Timms (1975) recorded that an earlier "lake full" year was 1896 and Bennett and Schwerdtfeger (1970) presented a collection of statements on the lake's condition over the period from 1870 to the present time. They claimed that lake full condition only occurs in association with periods of above normal rainfall. It is important to note that the term "lake full" in this context does not mean overflow into the adjacent Morass Creek drainage system.

The lake is bordered to the north by a low ridge of granite approximately 2 km long, and to the south and southeast by a low ridge beyond which is an extensive clay plain gently rising to the footslopes of the Dividing Range in the vicinity of The Sisters (Fig. 3). To the west of the lake, the basin rises through rolling to hilly topography to the watershed with the deeply entrenched Reedy Creek, and on the eastern side it is bounded by a narrow, sharply defined low ridge on which the township of Benambra is located. To the north, the

basin extends beyond the granite ridge on the lake shore as a gently rising mature landscape (Fig. 1).

Immediately to the east of the basin is the broad, alluviated valley of Morass Creek which, some 8 km to the north enters a deep gorge dissected through a flow of basalt which filled the ancient valley of the lower Morass Creek and short sections of the Gibbo and Mitta Mitta Rivers.

STRUCTURE OF THE AREA

The earliest published reference to the mode of formation of the lake appears to be a report by D. E. Thomas (1937) who noted several unusual land forms associated with the lake and suggested that it had been formed by stream capture. Thomas reproduced a map of H. S. Whitlaw (previously unpublished), showing a probable fault along the northern edge of the lake, delimiting the granite, and another fault, parallel, but about 0.8 km further north. However, he dismissed faulting as being responsible for the creation of the lake. Furthermore, he considered that the granite ridge was not related to the formation of the lake and suggested that its elevated position resulted from differential erosion.

A report by J. P. L. Kenny (1937) referred to the basalt flow in the lower Morass Creek and agreed with Thomas's suggestion that the Lake Omeo basin was isolated from the Morass drainage by sedimentation of its earlier outlet.

Hills (1975, p. 301) suggested that the lake was probably formed by back tilting of the block west of a north-south fault adjoining Benambra, with the consequent defeating of a tributary of Morass Creek. Talent (1965, p. 122) suggested that faulting which occurred during the Quaternary had played a part in its formation, and later (1969, p. 53) he described the long low ridge of sedimentary rock on the eastern boundary of the basin

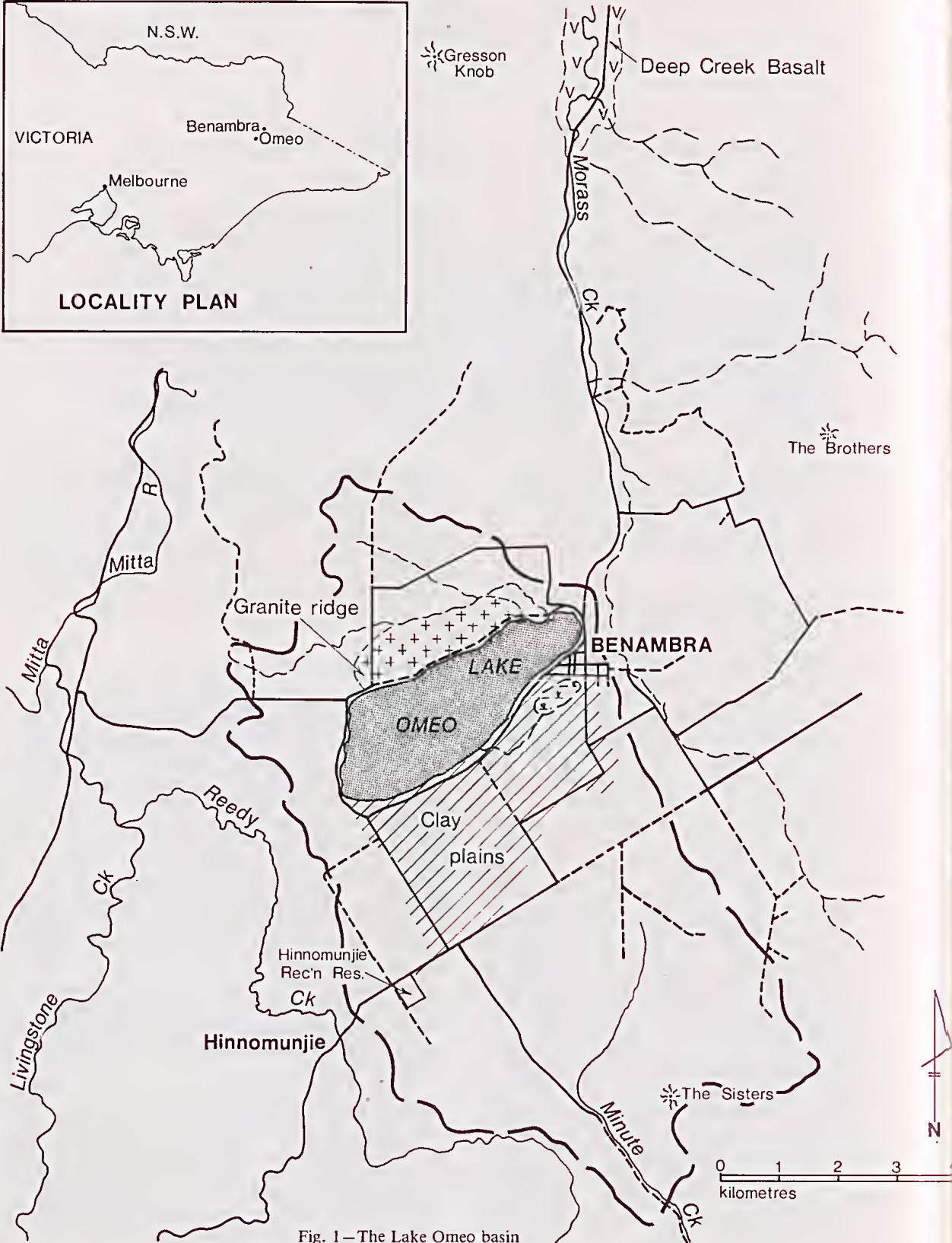


Fig. 1—The Lake Omeo basin



Fig. 2—The western end of Lake Omeo—1960.

as a small horst with its origin in the Pleistocene. He attributed damming of the lake to the horst.

Rowe (1967, p. 124) also associated faulting with the formation of the lake basin, and reported a considerable depth of alluvium in the basin so formed and the presence of two clay lunettes to the southeast of the lake, one being the lake-shore ridge (Fig. 4). The higher lake-shore or inner lunette forms a continuous ridge breached only by an ephemeral stream which includes the drainage of Minute Creek. The other lunette is south of the inner one and is lower and broken into several sections by local drainage (Fig. 5).

Both Thomas (1937) and Kenny (1937) referred to the basalt which blocked the early course of Morass Creek, and Thomas concluded that "Lake Omeo is thus a relic of a more extensive lake system". The basalt flow is referred to as the Deep Creek basalt as it is believed to have originated in the valley of that tributary of Morass Creek.

The streams have now incised the basalt to form a deep gorge and there is no ponding of water behind it except during flood flows, but before down-cutting commenced, water must have been ponded along Morass Creek for some 15 km and flooded the basin now occupied by Lake Omeo up to about the 715 m contour, the approximate level of the surface of the basalt. It is proposed to refer to this once extensive lake system as Lake Morass. Radiometric analysis of samples of the Deep Creek basalt resulted in two dates of 2.3 million years (Wellman 1974).

SUBSURFACE STRATIGRAPHY

Logs of bores sunk by a private contractor (M. Hob-

son, personal communication) in the 1940s and earlier, and of bores sunk under the supervision of the Victorian Department of Minerals and Energy in 1969, provide evidence of the subsurface materials. The locations of the Department bores are reasonably accurately known (Fig. 5) but others, except for the one in the north-eastern gap, have not been located in the field. Material from the Department bores is much disturbed but is useful in confirming the general grade of the material, its gross colour and the nature of coarse fragments.

Bores through the inner lunette, its lower slopes and the bed of the lake all indicate that grey or brown clays extend to beyond 40 m below the lake floor with occasional gravelly or stony strata, some of which contain useful water (Fig. 6). Water-bearing gravels were found at about 7.5 m below the level of the lake floor by several private bores in Benambra township, and at about 21.5 m in the clay plain south of the main lunette. Water was also found at about 33.5 m below the lake floor by Mines Department Bore Hinnomunjie No. 3. A private bore sunk on the western side of the north-eastern gap in the basin boundary struck rock at 9.1 m and a "waterbearing floor" at 18.3 m (M. Hobson, personal communication).

Water from one domestic bore in Benambra township contained 800 ppm total soluble salts at a time when water in the lake contained 2800 ppm (26/8/60) which seems to indicate a source other than a stagnant groundwater reservoir beneath the lake floor. The bore data indicate that the surface beneath the sediments is irregular and consists of granite in the north, and shales, which are present on the boundaries of the basin.



Fig. 3 — The Lake Omeo basin viewed from the southwest.

OTHER FEATURES OF THE BASIN

SANDY HIGH LEVEL BENCH

Coarse sandy sediments have been deposited by two streams which flowed into the lake from the north and west (Fig. 5). Sediments from the larger and more easterly stream extend toward the saddle in the basin boundary to the northeast, and beyond the southern edge of the granitic ridge to form a flat to gently sloping bench extending about 1.2 km along the southern flank of the ridge. The upper level of this bench is slightly below the level of the gap in the northeastern corner of the basin (Figs 7B and 8).

A 3-4 m deep excavation in the sandy bench near the northeastern corner of the lake, adjacent to the present course of the stream from the north, revealed several bands of silty material about 10 cm thick which dip in gentle curves towards the lake (Fig. 9).

The northeastern extension of the surface of the bench is clayey to a depth of more than 2 m and water accumulates in shallow depressions on it. A low levee has been constructed near the northeastern gap in the basin boundary to form a shallow dam. No such clay mantle exists over the southern part of the bench.

HIGH LEVEL FANS

Two large alluvial fans on the western slopes of the Benambra horst just south of the township (Fig. 5) have had their toes truncated at about the 700 m contour. Both fans have houses built on them.

LUNETTES

Two clay lunettes (Figs 5, 7, 8) on the southeastern side of Lake Omeo were recorded by Rowe (1967, p. 174). Several bores sunk through the inner lunette demonstrated that it consists entirely of clayey material. The results of particle size analysis of samples taken from a hole augured to 5.5 m in the top of this lunette (Fig. 11) are presented in Fig. 10. Clay contents of about 70 per cent are recorded generally below the surface 0.3 m, however, a horizon of only 45 per cent clay occurred between 3.0 m and 3.4 m from the surface. This corresponds approximately to the composition of the present surface soil and may indicate an earlier surface on which a soil formed.

The inner lunette is the higher and more continuous of the two. Its maximum height occurs near the centre of the ridge where its crest has an irregular, hummocky form (Fig. 11). It extends from the township of Benambra, where it merges with the horst of sedimentary rock, almost to the southern extremity of the lake where it gradually decreases in height to the level of the clay plain. It is breached by a small non-permanent stream which drains the greater part of the eastern half of the clay plain to the south of the lunette and includes the drainage of Minute Creek which has been channelled into a depression behind the lunette at the Benambra end. Drainage from the remainder of the southern part of the basin enters the lake at the southern end of the lunette.



Fig. 4—The inner lunette viewed from the south. The much reduced outer lunette can be identified by the rise in the left-hand fence line.

Another noteworthy feature of the inner lunette is the presence, towards its eastern end, of a flat to gently concave bench sloping up from the lake side to the crest (Fig. 8). The flat part of this bench is at approximately the same level as the tops of the sand deposits on the northern shore.

The outer lunette is broken into three short sections by drainage channels at the general level of the clay plain between the two lunettes. The southwestern section is the highest and the lowest is the eastern section. There is no obvious evidence of this lunette having extended east of a line extending southeast of the breach in the inner lunette.

The general level of the clay plain to the south of the inner lunette is some 4 m higher than the floor of the lake as shown in Fig. 7A. A number of crescentic depressions to the south of the two main lunettes may indicate the presence of other low mounds of lunette-type origin. Level traverse C, (Fig. 7A) shows a rise in level to the south of the outer lunette which may be the truncated relic of another lunette.

BEACHES

Several beaches are cut in both the southern and northern shores of the lake. Two main beaches are shown in Fig. 7A and 7B. Each is gently sloping and up to 20 m wide and has abundant limestone gravel on its surface. Numerous other lap-lines exist on the lunette shore. The recent highest water level (circa 1956-57) coincides with the lowest of the prominent lunette-shore beaches on the southern side of the lake.

On the northern shore, which is dominated by the sand deposit described above, the remnant strandline morphology is less well preserved than on the clayey southern shore.

THE CLAY PLAIN

To the south of the inner lunette, and extending from the foot of the Benambra horst in the east to near the Hinnomunjie Recreation Reserve in the southwest, is a flat to gently sloping plain. The regularity of its surface is broken only by the low ridges of the remnants of the

outer lunette and shallow drainage depressions including Minute Creek and the swamp south of Benambra township. Its southern margin is indented by low bedrock ridges which extend north from the slopes of the Divide which forms the southern boundary of the basin (Fig. 1). The material forming the plain is clay, as indicated in a number of holes augured to examine the soils.

POSSIBLE OVERFLOW GAPS IN THE BASIN BOUNDARY

Dumpy-level traverses were run to several low gaps in the eastern boundary of the basin. The gap in the northeastern corner was the lowest with a relative level (above a local benchmark established for the purpose) of 34.1 m, but the gap to the southeast of Benambra school was only slightly higher, 34.3 m. The cross-sections of the northeastern gap (along the road) and school gap are shown in Fig. 12A, B. The contour map shows all these gaps as being below 700 m elevation (Fig. 5).

SOILS

SOILS OF THE CLAY PLAIN

Examination of soils by auguring in the southwestern corner of the clay plain, near the Hinnomunjie Recreation Reserve has revealed the existence of a soil buried beneath dark clayey sediments (SCA Profile 550 Appendices 1, 2).

The upper soil is generally a very dark brown to black clay, about 30 cm thick. It has a clear to abrupt boundary with a lighter coloured and lighter textured horizon which is the A-horizon of the buried soil. The buried soil is a duplex soil (Northcote 1979) with an abrupt and wavy boundary between the A-horizon and a heavy clay B-horizon varying from about 6 cm to 10 cm below the buried surface. The upper B-horizon of the buried soil has weak structure but below 55 cm the structure is strongly developed with 1-2 cm blocky to prismatic peds which are coated with thick black cutans.

SOILS OF THE LUNETTES

The soils on the inner lunette are dark clays with a